Batteries Europe

Position paper

Social Sciences & Humanities Task Force

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CONTENTS

This project has received funding from the European Union's Horizon Europe
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ABBREVIATIONS AND ACRONYMS

Abbreviation	Definition
BE	Batteries Europe
BEPA	The Batteries European Partnership Association
BESS	Battery Energy Storage Systems
EV	Electric vehicles
GDP	Gross domestic product
ILO	International Labour Organization
ISCED	International Standard Classification of Education
LCA	Life cycle assessment
LFP	Lithium iron phosphate
PSILCA	A Product Social Impact Life Cycle Assessment database
R&I	Research and innovation
RRI	Responsible research and innovation
S-LCA	Social life cycle assessment
SDGs	Sustainable Development Goals
SET Plan	Strategic Energy Technology Plan
SETAC	Society of Environmental Toxicology and Chemistry
SRIA	Strategic research and innovation agenda
SSH	Social sciences and humanities
STEM	Science, technology, engineering, mathematics
TF	Task Force
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WG	Working group

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Executive Summary

In response to the need for a comprehensive understanding of the societal implications and human dimensions of battery technologies, the Batteries Europe/BEPA Task Force (TF) on Social Sciences and Humanities (SSH) presents this position paper. In contrast to most of the other TFs, TF SSH is one of the two recently established cross-cutting TFs and as such, the position paper presents the results of an initial exploration of the role of SSH in battery development and deployment.

TF SSH mission statement:

- **to strengthen the interdisciplinary framework of Batteries Europe through the incorporation of both STEM and SSH disciplines and identify research funding needs;**
- **to enhance understanding of different societal dimensions related to batteries in Europe;**
- **to engage in discussions regarding the societal dimensions with key stakeholders within the Batteries Europe platform;**
- **to raise awareness about the societal implications and human dimensions of battery value chain, aiming to ensure sustainable practices and equitable access to energy storage technologies.**

This position paper offers an **analysis of the current state of research within the 'SSH for Batteries' area, highlighting the complex interplay between technology and society.** It explores both technology-focused and human-centric viewpoints, raising critical questions about what characteristics make a battery not only technologically effective but also beneficial for society at large. The paper also emphasises the importance of recognising the needs and contributions of the industry, incorporating practical insights into the broader discussion.

The goal of this document is primarily to **inform the Batteries Europe community and other key players (interested stakeholders) on the need to integrate SSH disciplines and themes into the R&I agendas of battery technologies.** It aims to spotlight SSH research areas in need of Horizon Europe funding, underscoring the value of SSH insights in advancing battery technology development. Furthermore, the paper advocates for the development of an SSH framework specifically designed to address the challenges and prospects battery technologies offer along the entire value chain. It provides SSH research gaps and offers policy recommendations for enhancing SSH analysis of battery supply chains.

By presenting key findings and evidence from existing SSH research on batteries, the paper aims to **bridge the gap between technological advancements and the socio-cultural reality within which these technologies operate**. The outline framework for SSH aims to guide the Batteries Europe community in aligning technological progress with societal well-being. Recognising the synergies and overlaps between TF SSH and other Batteries Europe working groups and cross-cutting task forces, fostering collaboration, mutual understanding, and contributing to identifying new research gaps in the other cross-cutting areas of the battery technologies' research.

The research review reveals that existing SSH studies on batteries are mainly concentrated on economic and business aspects, enriched by insights from sociology and political science. These studies provide on one hand a deep understanding of the risks and opportunities in battery development, but on the other hand are missing more interdisciplinary frameworks to guide the process effectively.

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An outline SSH framework shows possible ways of the integration of SSH into the battery technology realm. By advocating for a transdisciplinary approach that merges SSH with STEM disciplines, the **TF SSH aims to foster effective research and innovation in batteries, establishing a foundation for structured collaboration between SSH and STEM fields in Europe's battery research and innovation landscape.** To demonstrate the concrete examples of incorporating SSH aspects in batteries technology, the paper presents examples of research projects, published case studies, as well as TF members' personal perspectives.

Case studies in the paper demonstrate how applying the SSH framework can enhance societal relevance in battery and renewable energy initiatives, offering insights from existing research on social risks, public acceptance, and policy drivers to inform future projects. Moreover, the paper identifies **gaps in SSH perspectives**, proposing a set of research questions to address these gaps and enhance SSH contributions to battery research.

Recommendations and broader policy implications for including SSH topics within the Batteries Europe community are presented, addressing potential challenges and obstacles, and policy implications within the context of the European and global clean energy transition.

In conclusion, this position paper invites Batteries Europe community, and other interested stakeholders including policymakers and industry stakeholders **to embrace a "human-centric paradigm", where SSH becomes an integral part of technological and societal progress.** It calls for collaboration and dialogue, and proactive measures, such as including SSH agenda in the innovation funding and implementation mechanisms.

1. INTRODUCTION

Highlights of this part:

- *Batteries are pivotal in the energy transition, enabling vehicle electrification, renewable integration, and mobile device operation.*
- *Battery demand surges by 30% annually, pressing for environmentally and socially sustainable practices.*
- *Advocates for sustainable battery innovation stress the importance of societal well-being and ecological integrity.*
- *The SSH Task Force advocates for battery development that champions social equity, environmental stewardship, and economic inclusivity.*
- *The document urges embedding SSH insights into battery research and policy frameworks for comprehensive sustainability.*

Batteries represent key enabling technology in the clean energy transition. They enable the electrification of the transport sector, support the shift of the electricity sector towards renewable generation technologies and are required for virtually all handheld and portable devices. In consequence, the global battery sector is predicted to grow at staggering rates of up to 30% annually and even more in short and near-term future[1]. While such rapid deployment of technology is required for achieving decarbonisation goals on time, it also brings along challenges related with environmental and social sustainability. Efforts are required to ensure that such a rapid development follows sustainability criteria, does not cause negative unintended or unforeseen side effects and that it is of overall benefit for society. Part of these aspects are addressed by the TF Sustainability and partially also by other TFs and Working Groups (WGs), however with focus on technology-centric aspects such as battery design or material choices rather than on society and its needs.

For this purpose, Batteries Europe has established the cross-cutting TF SSH with the aim to explore the role and potential of SSH research related to the European battery value chain. For instance, the expected high growth rates and corresponding rapid battery technology deployment raise concerns related with broader and more transcendent aspects of sustainability, including:

- **evaluating the impact of swift technological advancement on raw material source countries and their relationship with major consumers**
- **evaluating whether the current development paths and consumption levels can be sustained globally, while respecting planetary boundaries and sustainable development goals.**

The TF SSH has the objective to go beyond a pure technology focus in sustainability, aiming to understand the role of technology in patterning society – **both how such technology shapes society and society shapes such technology**. The TF does not consider batteries just for their own sake, but for their role in making society better i.e., less emissive, less environmentally destructive, fairer in energy use, but also ensuring that the lives of those affected by battery technology along its entire value chain and lifecycle are considered. This includes avoiding net negative designs and embrace net positive, where the calculus involves social concepts such as justice, inclusion and empowerment as well as technical, environmental, and economic ones. In this context, a "net negative" design refers to technology or solutions that, when considering their entire lifecycle and value chain, have an overall negative impact on society and the environment.

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Including SSH disciplines and domains is the way of identifying and characterising concepts relevant for understanding the role of technology in patterning society**.** In consequence, the thematic scope of the TF SSH overlaps with the TF Sustainability, including aspects of **foresight, of ethics and global supply chains, drivers of battery demand, global equilibrium models, and global distributional justice**. SSH can help with styles of innovation, appraisal of design options, understanding the contextual nature of spaces where batteries might go and what alternative designs might open up other opportunities and close down otherwise unnecessary risks. Furthermore, SSH contributes to identifying both evident and latent risks and threats, extending its benefits beyond innovators and manufacturers to encompass broader societal implications. Through its insights, SSH aids in enhancing governance mechanisms and promoting equity.

The present position paper charts the scope and calls for outlining a research agenda through the TF SSH, with the aim of giving SSH questions, especially the non-technical aspects of battery deployment, a higher visibility and relevance to the wider battery sector. **It identifies research needs for understanding how to reduce our demand for batteries and create acceptance where they are truly needed. Additionally, it recognises the necessity for shifts in habits or consumption patterns and investigates the influence of design on consumption behaviours.** By identifying how and where batteries can play a socio-technically optimal role, the TF SSH will generate impact by charting long-term viable and desirable development or deployment paths, widening the current technology-focused view towards envisioning a sustainable global battery economy. It will foreground the social purposes and benefits that current battery designs de facto have for society and explore design options in novel ways by seeing them equivalent to other (more consumption-oriented) sustainability measures, requiring interdisciplinary research projects.

This includes**:**

- **designing narratives for different types of actors**
- **creating storylines for the battery sector as a whole, with a global sustainability perspective**
- **defining the societal role of storage as a service and the most beneficial way of deploying it.**

As such, the position paper should feed into European, national and regional funding programs and research agendas by highlighting research needs for SSH disciplines, closing gaps that the technology-centred focus of the other TFs and WGs leave open and contributing to all-embracing sustainability guidance of the battery sector.

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2 CONNECTIONS TO WORKING GROUPS & TASK FORCES

Launched in 2016, the SET Plan's battery initiative is executed by Batteries Europe, the tech hub of the European Battery Alliance, which has been receiving backing from the European Commission since 2019. Originating from SET Plan action 7, which focuses on competitiveness in the global sector and e-mobility, Batteries Europe has evolved significantly. The initiative incorporates many of the original battery working group's experts and has welcomed numerous new stakeholders from industry, research, and national backgrounds.

The integration and collaboration among various WGs and cross-cutting TFs within Batteries Europe serve as a cornerstone for advancing battery technology and innovation. Overlapping areas between different WGs and TFs not only encourage interdisciplinary exchanges but also foster innovative solutions, enhancing the overall impact of the groups' work.

2.1 Working groups

The six WGs align with six research and innovation domains essential for establishing a competitive and sustainable European battery industrial manufacturing base. Within each of the WG focused on a distinct segment of battery value-chain, broader societal impacts (SSH overlaps) are identified below.

2.1.1 WG1: New and Emerging Technologies

Skill development: The introduction of new technologies may necessitate training and upskilling for workers to operate these advancements.

Job displacement: The adoption of emerging technologies might lead to shifts in labour demands, potentially affecting job stability and displacement.

2.1.2 WG2: Raw Materials and Recycling

Resource governance: Ensuring responsible and ethical sourcing of raw materials, implementing sustainable mining practices.

Community engagement: Involving local communities.

2.1.3 WG3: Advanced Materials

Health and safety: Considering the potential health and safety risks associated with the production and handling of advanced materials, implementing measures to protect workers.

Technology Access: Addressing potential disparities in access to advanced materials.

2.1.4 WG4: Cell Design and Manufacturing

Labour conditions: Ensuring fair and safe working conditions in manufacturing facilities, addressing issues such as working hours, wages, and employee well-being.

Supply chain transparency: Promoting transparency in the supply chain, ensuring ethical practices.

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2.1.5 WG5: Mobility Applications and Integration

Accessibility and urban planning: Addressing social equity concerns related to the accessibility of mobility solutions across different socioeconomic groups. Considering the social impact of mobility solutions on urban spaces and communities, issues related to congestion and public infrastructure.

2.1.6 WG6: Stationary Applications and Integration

Energy access: Ensuring that stationary applications contribute to improved energy access, energy poverty issues.

Community Resilience: Assessing and enhancing the resilience, reliability of communities where stationary applications are deployed, community engagement.

2.2 Task forces

The cross-cutting TFs were established to enhance cooperation among members of the WGs in transversal topics, broad-based thematic areas relevant across the entire value chain. These Task Forces are designed to address key challenges in these areas, offering advice and assistance to the WGs' activities.

2.2.1 TF Sustainability

The mission of the TF Sustainability is to evaluate and to pinpoint potential impacts of battery technologies on the environment and on resources. It considers environmental, economic and social impacts, the latter via the application of social life cycle assessment (S-LCA). In general, LCA approaches are technology-focused, with social LCA incorporating the use of materials and associated added-value (or working hours) with sector-specific 'social risks' (e.g., risk for child labour mainly related to raw material extraction). Therefore, they identify environmental, economic or social 'hotspots' along the value chain, without including broader social aspects of acceptance, justice, consumption patterns, sufficiency, which are foundational to SSH approaches. High potential for synergies exists between TF SSH and TF sustainability, with the TF SSH tackling questions that go beyond the horizon of the TF sustainability, while requiring input and exchange with it.

2.2.2 TF Education and skills

The latest Batt4EU/Batteries Europe SRIA highlights significant advancements in fostering new job opportunities within the battery value chain, notably through the identification and implementation of current educational initiatives. In addition, European requirements, emerging job roles, learning goals, and educational strategies for the industry are being analysed and classified. Numerous programs are underway across Europe to educate individuals and prepare future workforce through education, skill development, and retraining of workers.

By integrating battery-related content into school curricula, the sector not only educates young individuals about the importance and benefits of batteries but also fosters an early appreciation for sustainable energy solutions. The TF is putting forward the message of batteries as a net good for society, highlighting their role in providing sustainable, interesting, and well-paying jobs. Public learning labs and awareness campaigns can further demystify battery technologies, encouraging public engagement and support. Through these educational initiatives, the TF can leverage SSH to understand

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and enhance the societal impact of the battery sector, ensuring its development aligns with broader societal values.

2.2.3 TF Safety

Battery safety issues are crucial for gaining public trust and confidence in the transition to new energy systems. Ensuring that batteries are safe and do not harm the environment or the health of workers and users is vital for their widespread acceptance. Addressing these concerns is not only about preventing physical harm but also about fostering public awareness and trust in emerging battery technologies, which are essential for the successful deployment and adoption of these systems in society.

2.2.4 TF Digitalisation

The digitalisation of the battery industry holds potential social impacts too. Positively, it supports sustainability and resource availability, enhancing societal resilience and security. However, it also introduces risks like data breaches and infrastructure disruptions, which can lead to economic losses and affect daily life. These challenges highlight the need for strong cybersecurity, ethical practices, and inclusive policies to ensure the benefits of digitalisation are broadly shared and its risks are mitigated.

2.2.5 TF Hybridisation

This TF is dedicated to exploring energy storage applications that integrate two or more technologies and systems, with at least one involving batteries. The integration of batteries with other energy storage technologies yields innovative solutions that have the potential to reduce costs, enhance reliability and flexibility, and improve sustainability performance when compared to single-energy storage systems. These hybrid energy storage system applications find utility across various sectors, including industry, transportation, the energy grid, and buildings. Consequently, the scope of this TF is broad, with its alignment with the TF SSH primarily directed towards issues akin to those encountered in stand-alone battery applications. These may include considerations spanning social, economic, and environmental impacts on a larger scale, such as recyclability or disposal post-system lifespan, as well as issues linked to mining activities (e.g., community displacement, health hazards, land loss et al.). Additionally, concerns at the user level, such as safety, the presence of PFAS substances, operational aspects, recycling, and disposal, are also pertinent[2].

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3 SSH RESEARCH ON BATTERIES: THE STATE OF THE ART

Highlights of this part:

- *Systematic mapping reveals SSH research on batteries predominantly focuses on economic and business aspects, with substantial input from sociology and political science.*
- *Theoretical and analytical approaches within SSH offer insights into potential risks and opportunities in battery development.*
- *Various SSH and interdisciplinary frameworks exist that can effectively guide battery development and deployment.*

3.1 The scope of SSH

There is no single definition of what is included in the spectrum of the SSH disciplines. Fundamentally the framing of SSH here covers disciplines outside of STEM (Science, Technology, Engineering, Mathematics) disciplines. This represents a full spectrum of disciplines within the SSH, Education, Business, and Law sectors, drawing from the UNESCO International Standard Classification of Education, this itself being a reference point for the European Union Horizon Europe Programme[3]. *Box 1* sets the SSH disciplines out in full form.

Box 1: The scope of SSH defined by UNESCO

Social Sciences, Education, Business, and Law:

- Social and Behavioural Sciences: Encompasses studies in economics, the history of economic thought, political science, sociology, population studies, cultural anthropology (excluding physical anthropology), ethnology, future studies, psychology, human geography (excluding physical geography), peace studies, conflict resolution, and human rights.
- Education Science: Focuses on the development of curricula for both non-vocational and vocational education, strategies for educational evaluation and policy, and the pursuit of educational research.
- Journalism and Information: Includes disciplines such as journalism, the science of libraries and museums, documentation, and archival science.
- Business and Administration: Covers areas like merchandising, marketing, salesmanship, public relations, property management, finance, banking, insurance, investment theory, accountancy, audit practices, business management, and administration for public and private sectors.
- Law: Encompasses legal studies, the philosophy of law, and the historical study of laws.

Humanities and the Arts:

- Humanities: Encompasses religious studies, theology, studies in foreign cultures and languages (including those no longer spoken), literature of both ancient and modern languages, area studies, indigenous languages, colloquial and dialect literature, interpretation, translation, linguistic studies, comparative literature, history, archaeology, philosophy, and moral philosophy.
- Arts: Includes the fine arts, performing arts, visual and audio-visual media arts, design, and crafts.

[27] *UNESCO Institute for Statistics. "International standard classification of education: ISCED 2011." Comparative Social Research 30 (2012).*

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3.2 Research and concepts from SSH in batteries: an overview

To understand what research to date has been done in SSH on batteries within the restricted timeline and resources of the task force, **a brief, systematic mapping was undertaken leveraging the power of the online abstracting database Scopus.** Despite its recognised limitations, mapping the SSH literature this way allows for a snapshot of the kinds of research that have been developed over the last decade or two, providing an understanding of where the main gaps and focus are. For more detail on the method used to arrive at the mapping, see *Annex B*. In the process of mapping the research, groupings of SSH disciplines emerged into categories that reflected identifiable clusters of research. The final categories are shown in *Table 1* together with the number of instances that disciplinary perspective was present in the examined dataset. Overall, 153 different papers were identified, and each was coded for the presence of disciplinary areas as per *Table 1*. Since a paper can have more than one of these areas, the counts in *Table 1* add up to 193 instead of 153.

Disciplinary areas	Count	Proportion
Economics, business & administration	86	56%
Sociology, anthropology, human geography & related	48	31%
Political science and international relations	31	20%
Psychology and ergonomics, human factors and related	16	10%
Law, history and related	8	5%
Other	4	3%

Table 1: The six SSH categories used to code the academic SSH research on batteries and the proportion of the corpus codable by each category

Table 1, unsurprisingly, shows that the vast majority of SSH research on battery uses (to one degree or another) an economics and/or business-related lens. The 48 papers with a sociological approach formed the second most numerous category. If the sociological aspect is combined with political science, then a similar number of papers are identified as economic research, revealing an overall balance between economic and non-economic research on batteries. Further, a minority number of papers (13%) were categorised as using modelling or simulation one way or another, reflecting an important corpus of research that likely forms an interface with the wider STEM research in this area. Modelling is not included in the list of disciplines as it is qualified in this exercise as a methodological rather than a disciplinary area.

There is a clear emphasis here on the Social Science aspects of SSH which may in part be due to the search protocol *(see Annex B).* At the same time, there is a range of disciplines within SSH for which research on batteries seems unlikely (e.g., languages). The 153 papers therefore represent the core focus of batteries-related research in the SSH to date (at least in Western/Global North academic communities). Mapping research in this way provides insight into the range and value of SSH for batteries, as well as allowing a strategic analysis of research gaps which are explored in Section 6 of this Position paper.

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An alternative way to explore SSH's value is to examine how theoretical, conceptual and analytic approaches or methods have been developed that can reveal aspects of battery development – risks and opportunities – that might otherwise remain hidden. Now, attention is directed towards examining the potential contributions of SSH to the understanding of what constitutes effective battery technology in Europe.

3.3 Existing SSH theories, frameworks and methods applicable to batteries development and deployment

The above analysis employs systematic mapping of academic research to offer a platform for reflecting on where SSH could contribute more and where the research centre of gravity seems to reside. Next, the expertise across the TF is made use of to identify the kinds of ideas or approaches prominent in SSH for their potential to provide practical and impactful insight for Batteries Europe.

What role can SSH play in getting the best of batteries for society? Here, we consider ways of appraising the design, use and deployment of batteries, bring SSH questions to the fore. The focus here is on developing a *normative* stance (that is, thinking how and where batteries *should* be designed, deployed, and used) rather than a purely critical-descriptive approach (that is, identifying the problems with the way things are). In part this is due to the need to be compatible with the other normative approaches that are adopted by the more technical TFs and WGs as each of them, in their way attempt to set out what the 'best' batteries for Europe are.

Work by SSH scholars tends to emphasise certain concepts as central to technology transitions and development. These include inclusion and participation in decision-making, justice and equity in process and outcome and enabling resilience by supporting the vulnerable[2]. The challenge for SSH scholars lies in ensuring that these concepts are approached in ways that allow them to effectively influence and integrate with the existing processes of extraction, innovation, design, manufacturing, and distribution for batteries. *Box 2* highlights some established approaches that represent ways of thinking, methods and frameworks to bridge that gap developed by SSH scholars. One approach affiliated with SSH that stands out as the most obvious is economics[3,4]. We note an example of such approaches in *Box 2* as a further strategy to find ways of opening up how 'good' battery designs and strategies are appraised and enabling better connection with a wider set of SSH ideas and methods.

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Box 2: Theories, frameworks, and methods from SSH to inform and guide battery development

Energy justice[5,6] highlights and structures key concepts from justice and ethics in a way that enables consideration of choices in the design and deployment of resources, these comprise distributional, recognition, and procedural justice[7].

Responsible research and innovation[8,9] have been taken up by research funders in the EU and UK and by industry[10] as a means of driving forward a more societally sensitive approach to innovation. RRI emphasises anticipation, inclusion, reflexivity and responsiveness in the process of technology development and in appraisal of technology choices.

Value sensitive design[11] and **safe and sustainable by design**[12] provide approaches for thinking through how the engineering design process of new technologies can be explored to reveal implied values and determine if the values embedded are the ones intended or desired.

Recent work by Jenkins et al[13] has sought to **consolidate and combine** the above three concepts, advancing thinking in this area.

Social Life Cycle Assessment[14,15] S-LCA aims to incorporate social elements into the more commonly environmental focused method for assessing technologies and processes across their lifecycle.

Doughnut economics[3] is an appraisal framework to systematically consider macroeconomic elements not just in terms of GDP but in a range of other social and environmental units.

The approaches above provide frameworks and concepts that aim to bring social concepts to bear on choices around battery development and deployment. Other work in SSH identifies methods for collaborating across disciplines and communities for enabling the kinds of inclusive, participative and just goals embedded in the frameworks above.

Multicriteria mapping[16,17] aims to open up questions of risk in new technologies and reconcile different perspectives and values. This technique is different to multi-criteria decision analysis by embedding more open, unconstrained approach to incorporating criteria for appraising options.

Transdisciplinarity[18] and **participative systems mapping**[19] both provide guidance for how to integrate ideas across different expert and indigenous or local community knowledge – either at the team level or decision-analytic level using systems approaches.

The approaches in *Box 2* provide a starting point for considering how concepts and analysis from a range of social sciences can be brought to bear in the context of the choices faced in Europe when investigating the role of batteries in supply chains and product development to serve different purposes in society[1]. Each approach could play a significant role in various aspects, whether in the management of battery technologies, the design of systems, or the regulation of supply chains. These approaches can be evaluated for their ability to align or integrate with the concepts and methodologies typically used in engineering and economics, making them well-suited for the interdisciplinary and transdisciplinary efforts required by a platform like Batteries Europe.

[1] Some other SSH concepts and approaches that can be useful in this context include, for example, political sociology, innovation studies, social shaping of technology, actor-network theory, critical realism, social practice theory, social acceptance theory.

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4 AN OUTLINE FRAMEWORK FOR INTEGRATING SSH INTO THE BATTERIES EUROPE AGENDA

Highlights of this part:

- *A blueprint framework has been developed to explore the intersection of SSH, and battery technology, focusing on analysing their components and lifecycle stages.*
- *Mapping SSH research onto the battery lifecycle reveals a focus mainly on economic and sociological aspects, with substantial insights into raw material extraction and the end-of-life phase.*
- *Significant research gaps have been identified in the transport and distribution stages of the battery lifecycle, highlighting the need for broader SSH engagement.*
- *The adoption of a product lifecycle framework proves effective for integrating SSH perspectives, offering a comprehensive view from raw material extraction to disposal and recycling.*

The overarching goal of the TF SSH is to inform and influence Batteries Europe platform stakeholders of the benefits and possibilities of the SSH research in developing a competitive value chain for batteries in Europe and beyond. The challenge that SSH faces here is in finding clear points of purchase with the current work and perspective taken in BE while neither overlooking the critical role (as in both important and challenging) SSH plays in addressing societal outcomes from technology development, nor cherry-picking only the more aligned research approaches. In addition, the TF SSH has a responsibility to represent the broad array of disciplinary perspectives that scholars across these fields bring. It is a challenging square to circle. Our initial approach to addressing this is to provide an outline framework for how SSH and batteries might intersect. We build this initial framework by considering the ways SSH and batteries can be understood or broken down into component parts.

4.1 A frame for SSH: the disciplines

As a starting point we build on the prior breakdown of SSH into constituent parts, it's recognisable disciplinary components as set out in *Section 3.* In doing so, this approach enables a more direct identification of scholars from specific disciplines who could be engaged in research and innovation related to Batteries Europe. However, as we have seen in practice, the disciplinary names can be problematic and sometimes unsuitable for certain tasks, such as mapping academic research. Nevertheless, they provide a starting point for a framework which is a central task of the TF SSH.

4.2 A frame for batteries: product lifecycle

The other aspect of the framework is in relation to batteries themselves. Again, we face choices in breaking down the concept of a battery in a way that opens up opportunities for SSH input while also identifying commonalities with the ways batteries are understood in other TFs. The initial choice here is to use a standard product lifecycle approach to defining the aspects of batteries to which SSH can be seen as relevant. This, particularly, complements discussion on the LCA methodology in the Sustainability TF Position Paper. It also facilitates the application of a structured and inclusive framework to batteries, enabling a description that more closely matches the concepts of social

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sustainability. At the same time, a product lifecycle perspective doesn't easily capture other important aspects related to batteries, but which sit just outside or adjacent to it: workforce development, innovation processes including identification and characterisation of use cases and so on. These aspects are clearly important to TF SSH. For now at least, the main way of addressing these is via engagement with the other TFs (see Section 2 of the paper) and WGs.

One advantage of using a product lifecycle framework is that it includes the use of a battery (which is an obvious contact point with SSH) but as simply one stage among others - opening up opportunities for wider SSH engagement in batteries. It is important to remember that a battery's life cycle involves distributed communities of workers and users, from the extraction of raw materials through manufacturing and distribution, to end-use, reuse, recycling, and disposal. Understanding what a battery 'is' requires considering these aspects, and it is the role of the SSH community to represent these wider communities. The other advantage of the lifecycle approach is that it has a direct and obvious connection to forms of appraisal in engineering and product design that help define what 'good' batteries might be – life cycle assessment.

Life cycle assessment is an established approach, and with it the more recent forms of social life cycle assessment provide the basis for an analytic integration of engineering analysis and social ontology. Further, the emergence of social LCA (S-LCA, as noted in *Box 2*) means the wider SSH community has a ready-made platform to explore how a wider SSH insight can be integrated into a relatively technical appraisal approach. We see emerging examples of such social LCA in the case studies (*Section 5*). LCA as a method has multiple advantages but also some limitations compared with other frameworks which might also be useful and relevant here. These limitations include context specificity, data availability, time- consuming process and cost. Importantly, S-LCA has its own limitations: it generally does not directly provide information on whether a product should be produced or not, doesn't explore behaviour vs function and the geographical variety is limited[20] .

4.3 Alternative battery framing

Alternatives for representing batteries in the context of Batteries Europe - where the goal of the overall platform is "to develop and support a competitive battery value chain in Europe" - might focus more on value chain components or innovation stages (e.g., technology readiness levels[21]). These would potentially fit more directly onto the core goals of Batteries Europe which are about innovation and value chain enhancement. However, one argument against that is that these lenses are too narrow and may reduce the opportunity for an effective SSH input. For now, a lifecycle framing of batteries seems most useful or the least problematic.

4.4 Alternative SSH framing

What other ways are there of framing SSH? One alternative is to consider the key concepts central to SSH research. We identified some key concepts earlier in *Section 3* (concepts such as inclusion, participation, justice and equity). However, this can be readily expanded to a much broader list including power, structure, agency, practices, behaviour, habits, capital, networks, relations, governance and so on. This expanded list predominantly emphasises concepts from sociology, anthropology, and psychology. However, it notably omits key areas like acceptance, place, policy, and entrepreneurship, which are central to human geography, political science, and economics, and could be integrated as well.

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The challenge lies in determining methodological robustness, given the lack of a universally accepted structure or a definitive criterion for completeness. It's conceivable that the efforts of TF SSH alone may suffice, rendering additional frameworks unnecessary, or that various frameworks might be needed for different objectives. At this stage, TF SSH's goal is to initiate a discussion and foster exploration, employing the most suitable methods for the objectives that resonate most within the Batteries Europe community.

4.5 Mapping SSH research onto the outline framework

This initial outline framework for SSH in batteries can be seen as a **stimulus to SSH community engagement**, enabling a mapping of who is engaged in battery-related research, which disciplinary perspectives are missing, and provide **license for future engagement to explore the questions arising**. *Table 2* shows the value of this framework by taking the SSH academic research mapping in *Section 3* and applying lifecycle stage coding to each paper. Note that more than one lifecycle stages may be apparent in one paper, and for some where more than 3 stages are present (especially those using S-LCA) they were coded as cross-cutting.

Briefly, some patterns are observable from this initial coding of the research. Most SSH research on batteries centres around the economics (and related) approaches to battery use, followed by more sociological (and related) studies of use. Raw material extraction features significantly in SSH research mainly (geo)political-economic but with a clear if small corpus on anthropological issues related to extraction. Finally, economic studies of end of life (and associated recycling approaches) feature alongside psychological and human factors related research. **There are clearly gaps both in the lifecycle stages – transport (of materials) and distribution (of products) has limited SSH inquiry.** Perhaps most significant is the lack of political science (and related) studies on battery distribution given how significant this topic might be for Batteries Europe work.

	Economics	**Sociology**	**Pol. Sci.**	**Psychology**	**Law**	**Other**	**Totals**	**%**
Raw mat.	**20**	**12**	**19**	0	1	0	54	35%
Transport	2	0	2	0	sn0	0	4	3%
Production	**13**	5	7	0	0	0	25	16%
Distribution	4	6	0	2	2	0	14	9%
Use	**38**	**29**	5	**11**	3	1	102	67%
End of life	**17**	6	1	5	0	2	37	24%
X-cutting	6	2	5	0	4	1	21	14%
Totals	100	60	39	18	10	4		
%	65%	39%	25%	12%	7%	3%		

Table 2: Showing the number of SSH-coded papers also coded for the life-cycle stage they principally focus on

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The mapping above illustrates the potential value of the outline framework and provides insight for a key TF SSH output – to inform future research priorities. We return to these below. Before doing so, some key, illustrative research will be considered, showing how collaboration with stakeholders in battery technology can be facilitated by SSH. In part this helps ensure that the TF SSH contribution is pragmatic rather than abstract, but also provide stimulus to the wider SSH community to build on this work, gaps and issues they reveal. Further, the very existence of the outline framework here can be seen as just such a friendly 'provocation' to the SSH community to build on the early groundwork TF SSH has achieved in this short time.

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5 CASE STUDIES

Highlights of this part:

- *Case studies illustrate the application of the SSH framework in enhancing societal relevance within battery and renewable energy projects.*
- *Insights from existing research, such as social risks, public acceptance, and policy drivers, offer valuable guidance for future battery projects.*

In this section, the practical applications of the SSH framework are explored, showcasing how it enhances the societal relevance in battery and renewable energy projects. Through a selection of few **examples and case studies, the applications of the SSH framework are illustrated, to ensure that battery projects not only achieve technological milestones but also resonate with and benefit society**. This exploration includes the application of the SSH framework in battery technology projects, highlighting how social life cycle assessments, social acceptance and ethical considerations inform and shape battery production and usage.

1. **Social Risk Assessment of BESS Life Cycle**: Koese et al. (2023)[22] conducted a social LCA on vanadium redox flow and lithium-ion batteries, utilising UNEP/SETAC guidelines and the PSILCA v.3 database. Their findings highlight the primary social risks associated with battery life cycles, particularly in raw material extraction and chemical sectors, with workers being the most adversely affected stakeholder group. This study underscores the necessity of addressing social risks early in the battery's life cycle to mitigate adverse impacts on vulnerable communities and environments.

2. **Social Risk Profile of LFP Battery**: Research by Yi Shi et al. (2023)[23] on lithium iron phosphate (LFP) batteries through social LCA identifies significant concerns regarding corporate social compliance in the production of LFP batteries. This study contributes to the ongoing public debate on the ethical implications of battery production, emphasising the need for greater corporate responsibility and transparency in supply chains, particularly in China, Japan, and South Korea.

3. **Social Acceptance of Large Battery Storage[24]**: An examination of the societal acceptability of large stationary battery storage systems reveals that public acceptance is significantly influenced by the visual impact, location, and design of battery storage installations (Baur et al, 2023). An online survey method was used to gauge perceptions, indicating that aesthetics, environmental integration, and community engagement play critical roles in fostering societal support for renewable energy storage solutions.

4. **Ethical Considerations of Raw Material Extraction**: "*Cobalt Red: How the Blood of the Congo Powers Our Lives*" by Siddharth Kara[25] provides an ethnographic insight into the ethical concerns surrounding cobalt extraction in Congo, essential for mainstream lithium-ion batteries. Similarly, *Voskoboynik and Andreucci*[26] explore how lithium mining is presented as necessary to mitigating climate change in industrial settings providing a means to reflect on what kind of value is being generated for whom in the battery value chain.

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6 RESEARCH GAPS, POLICY IMPLICATIONS AND RECOMMENDATIONS

Highlights of this part:

- *Mapping SSH batteries research shows a gap in disciplinary perspectives at different lifecycle stages, highlighting both specific and potential unseen gaps.*
- *A categorised list of SSH-focused research questions aims to bridge these gaps, fostering SSH contributions to battery research through collective expertise.*
- *The questions we provide are not exhaustive but pivotal for exploring SSH priorities and concepts within battery research.*
- *Advocating for a transdisciplinary approach, integrating SSH and STEM fields is essential for effective research and innovation in batteries, as recommended by the TF SSH.*
- *The TF SSH's exploratory work lays foundational steps for structured engagement between the SSH and STEM communities in European battery research and innovation.*

As Europe accelerates its transition towards a more sustainable and electrified future, **the integration of SSH perspectives ensures that policies, innovations, and market strategies are rooted in societal needs and values, fostering public acceptance, and promoting responsible innovation.** By examining the cultural, social, and political dimensions of battery technology, SSH research can contribute to more inclusive and equitable energy systems, identify potential social barriers to technology adoption, and facilitate dialogue between stakeholders to align technological advancements with European societal goals.

6.1 Research gaps and questions

The mapping of the SSH batteries research in *Section 4* reveals one kind of gap – that of the disciplinary perspectives applied to specific lifecycle stages of batteries. This leaves open what specific questions might be asked in relation to those gaps as well as whether there are other kinds of gaps – gaps important for unlocking SSH value to batteries that are invisible with the outline framework described above. As a part of the TF SSH work, **we collectively developed a set of questions building on the individual expertise in the group to provide a categorised list of SSH-focused batteries research questions.**

6.1.1 Sustainability and Ethics

- How can the traditional *three-dimensional model of sustainability* (environmental, economic, and social) be critically evaluated and potentially redefined to more accurately reflect the complexities and interdependencies of sustainable practices, particularly in the context of economic and social dimensions?
- How do the *ethical considerations of deep-sea and Antarctic mining* for battery materials, particularly in high biodiversity or untouched areas, influence decision-making processes, and what frameworks can be established to balance resource extraction with environmental conservation and social responsibility?
- What strategic approaches and policy frameworks are essential to achieve a *just transition* to *a low carbon economy*, considering the Sustainable Development Goals (SDGs), and how can these

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strategies ensure equitable outcomes for all stakeholders involved in the lifecycle of battery storage systems?

- How do batteries contribute to well-being and life satisfaction? How much is battery needed for 'living a good life', and how much would be possible under a global perspective, respecting planetary boundaries and social minimum (sufficiency) requirements?
- How can *battery due diligence policies* be effectively designed and implemented to address social risks, including the protection of human rights, community life, indigenous peoples' rights, child protection, gender equality, and labour rights in accordance with international human rights law and ILO conventions related to the EU Batteries Regulation.

6.1.2 Engineering and Design Perspectives

- How do *battery design engineers* perceive and understand batteries? What reference frameworks do they employ, and how could the integration of SSH concepts alter these frameworks and their understanding?
- What are the constraints and priorities that shape the current *design and innovation strategies in the battery sector*? Who benefits or suffers from these strategies, and what viable alternative approaches can be proposed?
- What *unique characteristics and capabilities* do batteries possess when considered as independent units, and how do these attributes differ from their roles in electric vehicles and photovoltaic systems?

6.1.3 Policy, Socio-Economic Impacts and Geographical context

- In what ways do *policymakers conceptualise batteries*, and what explicit or implicit narratives guide their understanding? Are their perspectives influenced by considerations of sectoral growth, environmental limits, or economic models like the *doughnut economy*?
- What are the *socio-environmental impacts* of the expanding battery industry and rare mineral mining in Europe, and how do these developments affect land use, local communities, and environmental risk management?
- How can SSH be more effectively *integrated into battery-related policies* to address issues of *resource ethics, material neo-colonialism, and broader social impacts*, and what lessons can be drawn from the oil sector to anticipate and mitigate similar challenges in the battery industry?
- How do variations in *public policy and other contextual factors* across different countries influence the deployment and effectiveness of Battery Energy Storage Systems (BESS), and what can be learned from comparative analysis to guide future policy and technological advancements in energy storage?
- What SSH aspects are relevant to take into consideration during the *selection process for battery manufacturing* plants, and how do these aspects influence the design criteria for new battery developments?

6.1.4 Usage and Application in Society

- What are the *diverse and adaptive uses of batteries within household settings,* such as their role in car-to-home energy systems or in domestic heating systems when integrated with heat-pumps, as identified through ethnographic investigation? Does this lead to the expected empowerment of consumers towards prosumer, actively participating in the electricity grid?
- What are the *social and cultural ramifications of mining activities* for battery materials, with a specific focus on the extraction of rare earth minerals in Europe and other areas?

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- How do *towns that rely on the establishment of battery factories* for economic revitalisation manage their expectations and cope with the outcomes when such industrial projects are unsuccessful or unfeasible? How do /can towns deal with possible local environmental impacts of such factories?

6.1.5 Environmental and Industry Implications

- What are the *rebound effects* associated with the deployment of batteries in various sectors, and how do these effects influence the overall environmental and energy efficiency gains promised by battery technologies?
- What are the *key drivers behind the export and informal recycling of batteries*, and what effective remedies can be implemented to address the associated environmental, social, and economic challenges?
- What are the *potential long-term impacts of the global transition* to battery-based systems on the battery value chain, and how can foresight studies inform strategies to optimize benefits and mitigate negative outcomes across environmental, economic, and social dimensions?

6.1.6 Comparative and Future-Oriented Studies

- How can an *inter- or transdisciplinary evaluation framework* be developed to assess battery innovation and utilisation, which includes social and life cycle assessment methods?
- What are the critical *environmental, social, and economic impacts of establishing battery factories*, and how can these insights inform the strategic planning and assessment processes for future battery industry projects in Europe?
- How do variations in public policy and other contextual factors across different countries influence the deployment and effectiveness of BESS, and what can be learned from comparative analysis to guide future policy and technological advancements in energy storage?

These sets of questions are not meant to be seen as exhaustive, systematic or even necessarily strategic (though some do directly address gaps identified in *Table 2*). **It represents important areas of inquiry for SSH scholars in this area, based only on SSH-rooted priorities and concepts.** At the same time, a key part of developing an effective programme of research and innovation is the integration of perspectives across SSH and STEM – and ideally, inclusive of perspective outside of academic disciplines – so truly transdisciplinary. We expand on this point below as part of the research policy recommendations arising from the TF SSH.

Below we present three perspectives from TF SSH members:

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Box 3: Beyond social acceptance

"Social acceptance of batteries and connected mining industries is a tricky term, as it implies that battery production is legitimate per se. Deeper insights into complex social and natural assemblages are needed. As the battery industry and mining for rare minerals are increasingly established in Europe, so are the conflicts and challenges connected to land use, risks, and pollution."

[Zane Datava, NTNU, TF SSH Member]

Box 4: Unintended consequences

"Seemingly empty nature is being taken over and used for industrialisation in the name of a greener future. However, we must question how green this future is. A growing town, heavy traffic, construction sites, demographic tensions, and pressure on services may affect the citizens in these developing areas. Moreover, despite their low-carbon ambition, large-scale developments paradoxically contribute to an increase in carbon emissions and loss of nature. These developments are embraced simultaneously and quickly, exacerbating the negative consequences. A thorough examination of the areas for potential battery factories is needed before the implementation of the projects. As a pioneer in EV adaptation and a thriving battery industry, Norway is an example of conflicts in implementing the mining sites (Førdefjord, Repparfjord), protests and tensions in renewable energy sites areas (Fosen case, Trøndelag) and the collapsed industry hopes when the imagined battery factory is failing, and the production is moved abroad (Mo I Rana case)."

[Zane Datava, NTNU, TF SSH Member]

Box 5: Benefits of international comparisons

"Comparative analysis – both statistical studies and comparative case studies – allows for examining the effects on battery electric storage systems (BESS) of variations in public policy and other variables, for learning lessons between cases. It will be central to the advancement of knowledge of public policy in this domain. To date, much of the policy-related literature on storage and the deployment of BESS has had a single-country focus. Cross-national comparative studies are rare, and have examined the role of storage technologies in the decarbonisation of the North American countries and its dependence on resource availability, technology costs, and public policies have sought to examine the case of Australia in respect of batteries and gas storage and drawing lessons from several 'leaders' on storage (California, Texas/USA, Germany and Japan)."

[Marc Ayoub, University of Galway, TF SSH Member]

[Conor Little, University of Limerick, TF SSH Member]

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6.2 Policy implications and recommendations

The work of the TF SSH has been exploratory and aimed to lay the first foundations for a more structured engagement between the SSH and the STEM communities researching and innovating batteries in Europe. Hence, the policy recommendations are primarily addressing the evident capacity gaps identified through the preliminary assessment of SSH's role in battery research. Some clear challenges are present in the state of the art and the consequences of mapping the research capacity in the outline framework:

1. There is very limited research from or in the SSH approaches that focus mainly or exclusively on batteries.
2. What SSH research there is, tends to focus only on the use of batteries and to some extent the mineral extraction for battery manufacture.
3. The majority of SSH research is mainly or partly economics-related research. Other disciplinary perspectives are potentially underserved, especially those from humanities.
4. There is limited research that combines SSH and STEM perspectives effectively, and even relatively advanced methods such as S-LCA have clear limitations.
5. There are important SSH-related research questions that need addressing, but there is no structured forum or process to establish them across the SSH community.
6. The wider impacts of establishing a competitive value chain in Europe, particularly in the context of Widening EU countries[2], as well as its impacts beyond Europe (see Box 6), have not been thoroughly explored.

[2] An example of a Widening EU country Czechia project with batteries-SSH topic included is TwinVECTOR (grant agreement ID 10107835)

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Box 6: Battery value chain considerations beyond EU

The impact of new and sustainable battery technologies to be adopted in the EU would have significant impact in the *Global South*. The global south will be the largest producer and consumer of batteries worldwide. Hence it is important to think of an approach that is inclusive and equitable when it comes to new, sustainable batteries for Europe. More specifically there would be political, economic, social, technical, environmental and legal issues involved.

Political: Political forces in the global south are currently locked in a debate that involves negotiation with the developed countries for more time and financing to help them make a just and green transition. Such discourses negate the fact that green technology adoption is a global need today. There is a role for EU to build consensus among political parties in the global south about battery technology and adoption. Such consensus can help parties rise above electoral compulsions and bring in new laws for quicker adoption of upcoming technologies. To that extent, the EU can play a pivotal role by initiating dialogues with its stakeholders in the global south.

Economic: Companies manufacturing and using batteries have ambivalent attitude towards sustainable technologies. This is primarily driven by 1) the need for short term revenue and profit generation and 2) future strategies to adopt new battery technologies. The actual and emergent strategies will create tension in actual marketplace introduction and adoption of green technologies. Batteries Europe and similar initiatives should create pilot cases for global south industries and suggest incentives (rather than penalties) for early and easy adoption by exporters and market leaders. We can explore creating a separate project targeted at the global south for achieving this.

Social-ethical: The social cost (including health cost) for using unsafe and hazardous products and processes involved in battery value chain is highest in the global south. The battery chain involves work by the poor and marginalised groups who are largely unorganised particularly in the post-use phase. It is necessary to a) map vulnerable groups involved in the battery industry, b) provide them basic social security through provision of identity cards, health insurance and vocational training. Corporate social responsibility funds of leading companies can be utilised for this purpose.

Technological: The technology change cycle in the global south is likely to be long and complex given the high variation in product/technology cost and preference for affordable products/services. We would need engagement with future engineers and managers through leading engineering and business schools.

Environmental: The harsh environmental impact of used batteries has maximum environmental impact in the global south. We would need innovations for extending life of batteries but also large-scale campaigns to create awareness about the need to transition to new and safer technologies.

Legal: The relevant national standards in the global south will pose a major problem in adoption, use and disposal of batteries. We would expect industry bodies to take a stewardship role in lobbying with respective committees for an urgent review and upgrade of the standards.

[Subhasis Ray, XIM University]

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6.3. Research recommendations

To enhance the contribution of SSH researchers in battery research, the following recommendations propose establishing structures and funding mechanisms that support interdisciplinary collaboration, focusing on specific research gaps within battery value chain. They suggest initiating projects that broaden the scope of techno-economic considerations in battery research, fostering innovation and value chain analysis.

1. Develop structures and processes that enable SSH researchers to gain support and focus their research on batteries. This is likely to include specific funding streams but may extend beyond mere research project funding to include coordination and support actions that facilitate collaboration, visits, and centres of excellence.

2. Consider developing research project calls that aim to explicitly fill the gaps in the outline framework by naming life cycle stages. This could be prefaced by a collective of SSH scholars undertaking a deeper analysis of research to establish whether a different, more important set of gaps should be focused on, using alternative frames (see *Box 2*).

3. Create events, programmes of work and outlets that enable non-economics SSH researchers to work expressly on batteries, potentially starting with projects that develop and extend S-LCA approaches to take into account a wider idea of 'the social', but also to develop alternative framings or approaches, including those rooted in innovation (building on RRI) and value chain research.

4. Establish a forum for SSH researchers to collectively develop and debate key research questions in batteries research, that can inform research funding priorities across Europe.

5. Explore the potential for setting up a transdisciplinary engineering and research and innovation programme drawing on experience across Europe where similar programmes of work have been trialled in areas related to batteries.

6. Initiate a responsible battery value chain debate to critically examine and address the environmental, social, and economic implications.

These recommendations primarily focus on research policy, aimed at enhancing the capacity of SSH to provide significant and impactful insights in research and innovation

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7. CONCLUSION

The Batteries Europe/BEPA Task Force on Social Sciences and Humanities has crafted a position paper that aims to bridge the divide between technological advancements in battery technology and the socio-cultural dimensions within which these technologies operate. This document not only explains the current state of 'SSH for Batteries' but also provides research policy perspective over the interplay between technology and society.

Acknowledging the limited presence of SSH experts in the battery sector, the TF underscores the necessity of integrating SSH perspectives throughout the battery technology value chain. The task force's recommendations, based on analysis of socio-technical research, advocate for the integration of SSH insights across the entire value chain of battery technologies.

The call to action is clear: stakeholders, policymakers, and industry players must adopt a "human-centric paradigm," where SSH is not peripheral but integral to technological development. By encouraging dialogue, and inclusion of the SSH agenda in innovation funding and implementation, the task force envisions a future where technological advancements in batteries are synergistic with societal progress [27].

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ANNEX A – LIST OF CASE STUDIES

Battery SSH topic	Battery technology	SSH Method(s)	Conclusion(s)/ comments	Reference
Social risk assessment through the whole BESS life cycle	Vanadium redox flow battery, lithium-ion battery for BESS applications	Social LCA based on UNEP/SETAC guidelines and PSILCA v.3 database	The primary social risks associated with the life cycle of batteries typically emerge during the raw material extraction stage, with additional significant risks present in sectors related to chemicals. Among the various stakeholder groups, workers are the most affected	Koese, M., Blanco, C. F., Vert, V. B. & Vijver, M. G. A social life cycle assessment of vanadium redox flow and lithium-ion batteries for energy storage. J. Ind. Ecol. 27, 223–237 (2023). https://doi.org/10.1111/jiec.13347
Social risk profile of LFP battery	Lithium iron phosphate battery	Social LCA	"The conclusions provide a core concern for the eager public discussion of LFP battery corporate social compliance"	Shi, Y., Chen, X., Jiang, T. & Jin, Q. Social life cycle assessment of lithium iron phosphate battery production in China, Japan and South Korea based on external supply materials. Sustain. Prod. Consum. 35, 525–538 (2023). https://doi.org/10.1016/j.spc.2022.11.021
Social acceptance of large battery storage	Stationary battery storage	Online survey is conducted by examining the visual impact (location and design) of BS on acceptability	Societal acceptance of large stationary battery storage systems is strongly shaped by their visual appearance, location, design, and factors like aesthetics, environmental integration, and community involvement in supporting renewable energy storage solutions.	Baur, D., Emmerich, P., Baumann, M. J. & Weil, M. Assessing the social acceptance of key technologies for the German energy transition. Energy Sustain. Soc. 12, 4 (2022). https://doi.org/10.1002/ente.202201454
Raw material	Mainstream Li-Ion batteries	Ethnography/field research	Ethical concerns surrounding cobalt extraction in Congo, essential for mainstream lithium-ion batteries.	Cobalt Red: How the Blood of the Congo Powers Our Lives by Siddharth Kara Saint Martin's Griffin,U.S., 2023

ANNEX B

It is non-trivial to find SSH literature on Scopus because the way academic papers are classified is not completely transparent, and of course the breadth of disciplines and perspectives involve is broad. What we report here is a brief overview of a relatively extensive process that sought to identify research relevant to the task force, and fitting within the definition outlined above.

Summary of the search protocol

Academic papers were searched for in Scopus only. Only papers published after 2000 were included in the search, with the view that the key types of batteries in focus are those that are large electrochemical storage technologies, as per Batteries Europe scope. Four searches were conducted, and the results first checked for scope, and then de-deduplicated. In each search, 'battery' was a key term searched for in the title, abstracts or keywords of records. Scopus automatically includes plural variants (e.g. 'batteries') in such searches.

The identification of SSH papers used 3 separate techniques (use of search terms, Scopus 'Subject area' classifications) and journal titles identified as SSH oriented over 4 searches:

1. Use the Scopus 'Subject Areas' classification, and **limit to** social science areas
2. Same as 1, but **exclude** subject areas not defined as social science
3. Augment the basic search to "battery AND (society OR social OR human OR people)"
4. Limit the search to within 19 social science-oriented journals

Exclusion criteria

Returns from all the above were scoped manually for inclusion. Key criteria for exclusion were:

- Not about batteries in any way. Battery is a synonym used in psychology, law and the military

Inclusion criteria

To be included in the final count, all those not excluded by the process above, where then subject to a second sift to identify paper that were:

- Clearly approaching the subject with a recognisable SSH perspective, broadly defined
- Where batteries were a significant or central part of the paper, not just a background concept

Across the 4 searches set out above, an initial 1599 records were deemed in scope following the application of the exclusion criterion. Following application of the inclusion criteria above, 153 records were deemed SSH research on batteries. It is worth noting that this is clearly a relatively small corpus on what is otherwise a relatively large field of research. For context, a basic search for batteries as above (in titles, abstracts and keywords), limited to keyword "lithium-ion batteries", around 86,000 records are identified. Within this, if the subject areas are limited to SSH, around 1800 records are identified, around 2% of that literature. Once a more manual search is applied, only around 10% of those 1800 are within the scope, representing around 0.2% of the initial 86,000.

Mapping the returns

Using the titles, abstracts and sometimes journal titles, an attempt was made to map them against social science disciplines. Ideally it would be good to be able to map them against the full typology set out above, but in practice it is not so simple. Instead, it was easier to identify general sub-categories of SSH disciplinary focus of the paper across 6 categories, including one that is more method than discipline – modelling. It made sense to label these separately in part because it was often difficult to attribute such studies to particular disciplines, but also because they are so common in the corpus. Papers were multiple-coded so each record could be marked both political science and economics, for instance. No weighting was added to these.

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